Pedobiologia, Bd. 4, S. 35—42 (1964)

Department of Zoology, University College of Wales, Aberystwyth, Wales

A Study of the distribution of Soil Collembola in three small areas in a coniferous woodland

By T. B. Poole

With 2 figures in the text

(Received May 1963)

Contents

1. Introduction 35
2. Habitat 36
3. Methods 36
4. Results 37
4.1 Numbers of Collembola recorded 37
4.2 Species composition 37
4.3 Aggregations of Collembola 38
4.4 Relationship between Collembola and physical factors 38
4.5 Distribution of Collembola in relation to the trees 40
5. Discussion 40
6. Summary (Sommaire) 41
7. Acknowledgments 42
8. References 42

1. Introduction

One of the most characteristic features of the populations of soil Collembola is the patchy nature of their distribution. If an area of their habitat is randomly sampled, using a soil corer, most of the soil cores will be found to contain a few specimens of Collembola but a minority of cores will contain relatively large numbers (see Macfadyen 1952, Haarløv 1960.)

This aggregated pattern of distribution could either be the result of gregarious behaviour on the part of the Collembola or be due to a pattern of scattered, highly favourable micro-habitats, or to a combination of these two factors. The evidence of previous work in a Douglas fir plantation in North Wales had favoured the second hypothesis in that different species of Collembola were usually numerous in the same places so that aggregations were not mono-specific (Poole 1961). It had also been shown that the numbers of Collembola in the soil cores were related to the moisture content and depth of the organic layer of the soil, so that a deep, moist organic layer generally supported the largest numbers of Collembola. The pattern of collembolan distribution in the plantation also bore a definite relation to the arrangement of the surrounding trees (Poole 1963), the numbers of Collembola occurring around the base of a tree being smaller than those found mid-way between two adjacent trees.

It was therefore decided to study the problem further by investigating the patterns of distribution of Collembola in small areas between adjacent trees in a plantation in Denmark where climatic conditions and the species of tree were different from those of North Wales.

Two patterns of sampling were adopted, firstly a very small area was intensively sampled, the corers being placed side by side so that the area was covered very fully; secondly the

area between four trees was systematically sampled by means of a grid designed to give a series of transects both across the area and along its margins (see Fig. 1).

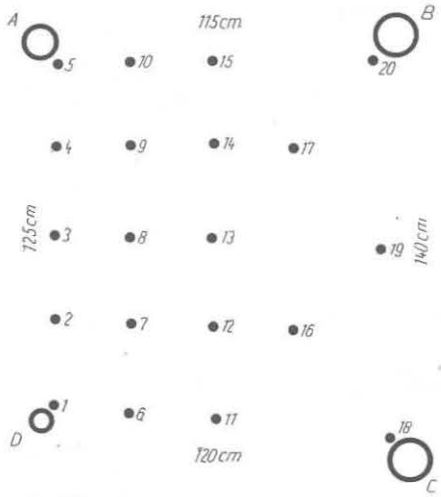

Fig. 1. Diagram showing the 'grid' pattern of sampling and its relation to the trees. The cores are numbered 1—20.

2. Habitat

This work was carried out in a *Picea abies* LINN. plantation at Hestehave, near Rönde in Denmark. The trees were between twenty and thirty feet in height and were planted in straight rows at 1¼ m intervals; the plantation was very dense and dead branches were present almost to ground level. The wood was selected because of its even layer of litter and the absence of ground flora apart from occassional patches of moss or fungal fruiting bodies.

The soil profile was examined; the litter and fermentation layers were together approximately two centimeters in depth and between the two layers a dense mat of fungal hyphae was present. The humus layer was approximately one centimetre in depth but the mineral soil was discoloured with humus to a depth of approximately six and a half centimetres below the humus/soil interface. The soil was a coarse sandy silt, the proportion of sand increasing with depth; below twenty-six centimetres flints and stones were found and at approximately thirty-five centimetres red pieces of iron oxide occurred.

3. Methods

The Collembola were extracted from intact soil cores of 4.7 cm diameter with an apparatus consisting of twenty modified Tullgren funnels (see POOLE 1961).

The samples were taken in the following way; three areas were selected approximately 1.5 m square with a standing tree at each of the four corners and an even floor of litter with a minimum of ground flora. The areas chosen were as close together as possible, though they were not adjacent; all plots were within 10 m of each other.

Intensive Sample. Two patterns of sampling were adopted and in the first area sampled on August 29th 1957, the twenty cores were taken as close together as possible without unduly disturbing the litter; this will henceforth be referred to as the "intensive" sampling method. The size of the restangular area sampled by this method was 25×30 cm.

Grid I Sample. The "grid" method of sampling, illustrated in Fig. 1 was carried out twice on the remaining areas. The following measurements were recorded from the Grid I area which was sampled on the 4th September 1957. The tree girths at their base were: A 33 cm, B 45 cm, C 41 cm, D 19 cm; the lengths of the sides of the grid were: AB 115 cm, BC 140 cm, CD 120 cm, DA 125 cm; the diagonals measured: AC 190 cm, BD 170 cm. At the bases of the trees, especially B, there were some fine twigs lying on the litter surface; in addition, fruiting bodies of *Mycena vulgaris* QUEL. and *Lycoperdon echinatum* PERS. were present but they were not included in the samples; there was a slight gradient across the area with B at the highest point.

Grid II Sample. Similar measurements and observations were recorded for the Grid II area which was sampled on 10th September 1957 with the following results: the tree girths at the base were: A 40 cm, B 62 cm, C 20 cm, D 56 cm; the lengths of the sides of the grid were: AB, BC and CD each 145 cm, DA 125 cm; the diagonals measured AC 200 cm, BD 190 cm. Near tree A was the remains of a dead dicotyledonous tree approximately 1 metre high; fruiting bodies of *Mycena vulgaris* were common and were included in cores 1, 6 and 12 but had no obvious effect on the numbers of Collembola. In both grids there was a break in the canopy above the centre of the area.

The soil cores remained in their containers but were covered at each end with polythene sheeting during transit, to prevent desiccation and the escape of the more active Collembola. The following data were recorded for each core: total numbers of Collembola and the numbers of the common species of Collembola extracted, the depth of the organic layer, the weight of organic matter, the weight of mineral ash, the fresh weight, and the dry weight after oven drying to constant weight at 100 °C. The core moisture content was expressed as a percentage of the dry weight of the core. To obtain the maximum number of cores only the organic layer of the soil was sampled down to the humus/mineral soil interface as the great majority of the Collembola are found in the organic layer.

4. Results

4.1. Numbers of Collembola recorded

The mean numbers and variances of the six commonest Collembola are shown in Table 1 together with the physical data of the samples. Collembola were numerous in the areas sampled, in the intensive sampling every cubic centimetre of the organic layer contained an average of 1.1 Collembola whilst in Grid I an average of approximately 1.7 Collembola per cc were recorded; for Grid II the figure was 1.2 Collembola per cc.

Table 1 Means and Variances

a) Collembolan Species	Samples					
	Intensive		Grid I		Grid II	
	Mean	Variance	Mean	Variance	Mean	Variance
Tullbergia krausbaueri Börner	4.00	**34.5**	2.3	**30.71**	3.75	**46.99**
Folsomia quadrioculata Tullberg	21.40	**181.34**	50.25	**2220.60**	0.55	**1.05**
Isotomiella minor (Schäffer)	0.50	**0.55**	7.90	**67.19**	4.65	**34.98**
Isotoma notabilis Schäffer	9.40	**50.84**	12.05	**132.65**	24.35	**1209.53**
Lepidocyrtus lanuginosus (Gmelin)	3.10	**1.99**	4.35	**9.13**	3.85	**7.53**
Pseudosinella alba (Packard)	3.65	**12.12**	4.00	**9.90**	0.75	**0.29**
Other species	3.40	**20.02**	9.00	**163.42**	6.80	**43.24**
Totals	45.45	**613.95**	90.30	**2992.10**	44.65	**1920.45**
b) Physical Data						
Dry weight of core (gm)	13.07	**3.76**	12.92	**4.50**	14.69	**4.94**
Moisture content of core (%)	75	**13**	62	**23**	66	**22**
Depth of organic layer (cm)	2.35	**1.10**	3.15	**2.30**	2.10	**1.15**
Weight of Organic Matter (gm)	3.53	**0.52**	4.71	**1.55**	4.32	**0.97**

4.2. Species composition

The three areas differed considerably in their species composition (see also Table 2), *Folsomia quadrioculata* was the most variable species numerically, being very common in two of the areas and virtually absent from the third (Grid II). *Isotomiella minor* and *Isotoma notabilis* also showed considerable variations in the three areas. Each area had one species making up almost half of the total collembolan population, in the "intensive" and "Grid I" samples this species was *F. 4-oculata* whilst in "Grid II" it was *I. notabilis*. The average numbers of Collembola in Grid I were double those found in the other areas.

Table 2 Percentage species composition

Species	Sample		
	Intensive	Grid I	Grid II
T. krausbaueri	9	3	8
F. 4-oculata	47	56	1
I. minor	1	9	10
I. notabilis	21	13	55
L. lanuginosus	7	5	9
P. alba	8	4	2
Other species	7	10	15
Total	100	100	100

4.3. Aggregations of Collembola

The distribution of the Collembola in the area intensively sampled showed little evidence of aggregation but a slight trend in this direction was indicated by the high, though not statistically significant, variance: mean ratios and by the fact that in most species two-thirds of the core totals were below the mean.

When the cores were taken from an area between twenty and twenty-five times larger (Grids I and II) the relative variances were higher and a patchy overall distribution was revealed; a number of species had statistically significant relative variances (see Table 3).

The fact that the Collembola were aggregated made it necessary to transform the data into square roots or logarithms to obtain an approximately normal frequency distribution suitable for further statistical analysis.

Table 3 Variance: Mean Ratios

Species	Sample		
	Intensive	Grid I	Grid II
T. krausbaueri	8.62	13.35***	12.53***
F. 4-oculata	8.47	44.19*	1.90*
I. minor	1.11	8.51*	7.52**
I. notabilis	5.41	11.01*	49.67***
L. lanuginosus	0.64	2.10	1.95
P. alba	3.32	2.48	0.39
Other species	5.89	18.16***	6.36*
Totals	13.51	30.90	43.0**

Symbols: * $0.05 > p > 0.01$, ** $0.01 > p > 0.001$, *** $0.001 > p$.

4.4. Relationship between Collembola and physical factors

The figures for the correlation coefficients for the three samples are shown in Table 4 but the results obtained are certainly not consistent with those obtained in North Wales where the numbers of Collembola were positively correlated with the depth and moisture content of the organic layer. In fact the Hestehave results are very difficult to interpret, only *Pseudosinella alba* showing any positive correlation with the depth of the organic layer. The correlation coefficients for the physical data are shown in Table 5.

The numbers of most of the species of Collembola show significant correlations one with another in the intensive sampling although *P. alba* is an exception. In the samples from the Grid I and Grid II areas the numbers of the different species bear less relation to one another.

Table 4 Correlations between Collembola and environmental factors

Species	Environmental Factor	Value of "r"		
		Intensive	Grid I	Grid II
T. krausbaueri	Moisture Content	0.292	—	0.002
	Organic matter	— 0.614**	—	— 0.448*
	Depth	— 0.212	—	— 0.296
	Dry weight	— 0.494*	—	— 0.226
F. 4-oculata	Moisture content	0.192	0,378	—
	Organic matter	— 0.430	— 0.346	—
	Depth	— 0.097	0.365	—
	Dry weight	— 0.340	0.099	—
I. minor	Moisture content	—	0.269	— 0.024
	Organic matter	—	0.074	— 0.050
	Depth	—	0.141	— 0.364
	Dry weight	—	0.009	0.184
I. notabilis	Moisture content	— 0.144	0.312	— 0.052
	Organic matter	— 0.129	0.049	— 0.167
	Depth	— 0.090	— 0.106	— 0.440*
	Dry weight	— 0.161	— 0.142	— 0.016
P. alba	Moisture content	— 0.103	—	—
	Organic matter	0.496*	—	—
	Depth	— 0.217	—	—
	Dry weight	— 0.122	—	—

Symbols: * $0.05 > p > 0.01$, **$0.01 > p > 0.001$.
N. B. *L. languinosus* had a nearly random distribution and was therefore omitted.

Table 5 Correlations between environmental factors

Factors	Values of "r"		
	Intensive	Grid I	Grid II
Organic matter (gm) × Depth (cm)	0.293	0.721***	0.118
Organic matter × Dry Weight (gm)	0.875***	0.308	0.371
Organic matter × Moisture Content (%)	— 0.626**	0.071	— 0.248
Depth × Moisture Content	0.036	0.099	— 0.165
Depth × Dry Weight	0.195	0.503*	— 0.254
Moisture Content × Weight	— 0.781***	— 0.711***	— 0.715***
Moisture Content × wt. of Ash	— 0.750***	— 0.776***	— 0.609***

Symbols: * $0.05 > p > 0.01$, ** $0.01 > p > 0.001$, *** $0.001 > p$.

Table 6 Interspecific Correlations

Species	Values of "r"		
	Intensive	Grid I	Grid II
I. notabilis × *I. minor*	—	0.226	0.082
I. notabilis × *F. 4-oculata*	0.618**	0.357	—
I. notabilis × *T. krausbaueri*	0.666***	— 0.101	0.474*
I. notabilis × *P. alba*	0.400	—	—
I. minor × *F. 4-oculata*	—	0.077	—
I. minor × *T. krausbaueri*	—	0.352	0.166
F. 4-oculata × *T. krausbaueri*	0.679***	— 0.268	—
F. 4-oculata × *P. alba*	0.176	—	—
P. alba × *T. krausbaueri*	— 0.026	—	—

Symbols: * $0.05 > p > 0.01$, ** $0,01 > p > 0.001$, *** $0.001 > p$.

4.5. Distribution of Collembola in relation to the trees

Previous work (POOLE, 1963) had shown that in a Douglas fir plantation in North Wales, the numbers of Collembola tended to decrease towards the base of a tree and the "Grid" method of sampling employed at Hestehave was designed to discover whether this situation was true in a plantation of *Picea abies* in very different climatic conditions. Analysis of variance was used to compare the data from the cores most distant from the bases of the trees (cores 3, 8, 11, 12, 13, 14, 15 and 19) with those closest to the tree bases (cores 1, 2, 4, 5, 6, 7, 9, 10, 16, 17, 18 and 20) (see Fig. 2).

None of the measured physical factors showed any difference between the two groups of cores but the aggregate number of every species of Collembola was greater in the cores distant from the bases of the trees than it was in those close to them. In *F. 4-oculata* this difference was highly significant in Grid I ($p < 0.001$), in *I. minor* it was significant in Grid II ($0.01 > p > 0.001$). The total figures for Collembola gave significant results in Grid II ($0.01 > p > 0.001$) and when the data for the two grids was combined a highly significant result was revealed ($0.01 > p > 0.001$).

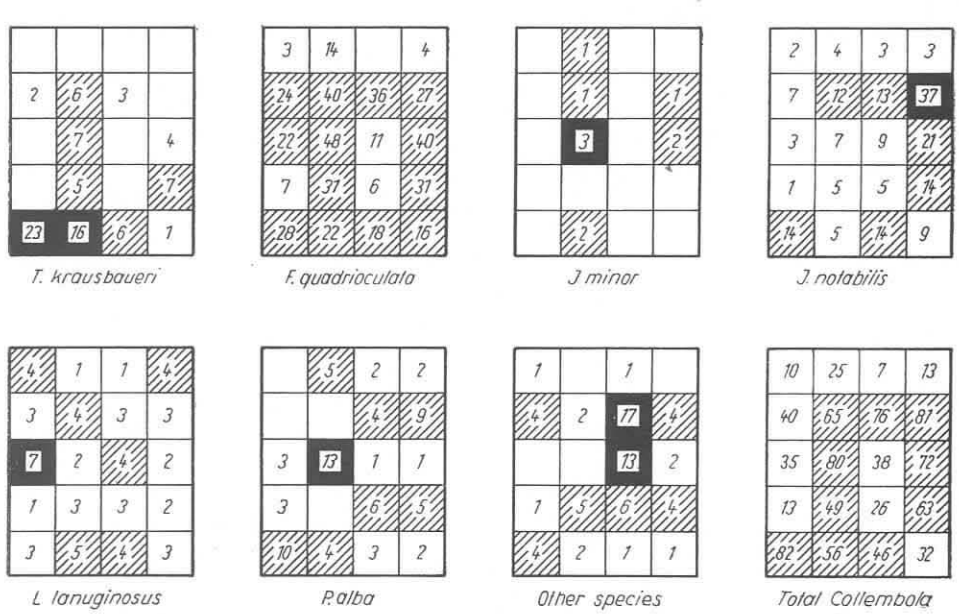

Fig. 2. Results of the 'intensive' sampling. The number of individuals in the core is recorded in each square. The black squares contained values over two standard deviations above the mean, the cross-hatched ones values 0—2 S D above the mean and the remainder were 0—2 S D below the mean.

It was therefore shown that a gradient in the numbers of Collembola from the base of the trees occurred in two coniferous plantations where the species of tree and the climatic conditions were different. It is therefore possible that this type of gradient may exist in many coniferous woodlands where the ground flora is at a minimum and the trees provide an even canopy.

5. Discussion

An interesting fact shown by the results of the correlations is that, in a small area, the numbers of the commonest species show strong positive correlations, although in an area only twenty times larger the same is not true. This suggests that, within a small area, aggre-

gations of the commonest species are found superimposed in favourable micro-environments where the conditions are optimum for all species, probalby owing to their similar basic requirements. On a larger scale, however, greater heterogeneity results in varying species composition throughout the area; hence in the grid samples, although the different species of Collembola have superimposed aggregations (as shown by the high variance: mean ratios of the total figures) the species present in each core are not the same, so that no over-all correlations can be demonstrated between the common species. These results indicate less homogeneity in the areas under consideration than in the Waen Wen experimental area where correlations between species were found in very large scale random sampling (see POOLE 1961).

The larger numbers of Collembola in cores distant from the tree bases, as compared with those closer to the tree, which had been found in North Wales were also observed here. It had been thought previously that a gradient in the depth of the organic layer might, in one species (*I. notabilis*), account for this phenomenon but it can now be seen that this explanation does not agree with the facts in this present study, where none of the recorded environmental factors could have produced any such gradient in numbers. It seems possible that gradients of this type may be a common feature of many coniferous woodlands, and for this reason, one possible hypothesis will be advanced, namely, that the gradients may be the result of the effect of the tree roots on the collembolan fauna.

Active mycorrhizal root tips occur in the organic layer (mostly in the F and H horizons), and observations in other coniferous plantations show that the number of active mycorrhizal root tips is greater as the distance from the tree base increaes. Mid-way between four trees, the active rootlets of all four trees ramify in a close network throughout the organic layer, whereas at the base of a tree the number of rootlets is relatively small. The influence of the roots on the Collembola may be an effect of the rhizosphere; Collembola may be most numerous in the region of the roots because of the increased biological activity resulting in greater amounts of available food.

6. Summary

Samples of soil Collembola were taken from a *Picea abies* plantation at Hestehave in Denmark. The Collembola were extracted from the organic layer of the soil profile using a modified Tullgren funnel. Three small areas were systematically sampled in order to gain some information on the patterns of distribution of Collembola.

The average numbers of Collembola in the three areas ranged from 1.1 to 1.7 per cubic centimetre of the organic layer. The proportions of the most numerous species present varied widely in the three samples. The numbers of individuals per core of three common species showed strong positive correlations in a small area, but not in the cores from a larger area.

Correlations between the numbers of Collembola and certain environmental factors yielded results which were inconsistent with previous work and difficult to interpret.

The characteristically aggregated pattern of distribution of soil Collembola was found in this area.

The numbers of Collembola in cores taken near the base of a tree were fewer than in cores taken further from the base of a tree. It was suggested that this may be due to the influence of the rhizosphere.

7. Sommaire

Des prélèvements de collemboles de terre ont été pris dans une plantation de *Picea abies* située à Hestehave au Danemark. Les collemboles ont été extraits de la couche organique du profil de terre au moyen d'un entonnoir Tullgren modifié. On a pris les prélèvements d'une manière systématique dans trois petites pièces de terrain afin de gagner quelques renseignements sur la répartition des collemboles.

Les nombres moyens de collemboles dans les trois pièces de terrain se sont échelonnés de 1.1 à 1.7 par centimètre cube de la couche organique. Les proportions de l'espèce la plus nombreuse

qui était présente ont varié beaucoup dans tous les trois prélèvements. Les nombres d'individus par noyau de trois espéces communes ont démontré de fortes corrélations positives dans une petite pièce de terrain, mais non pas dans les noyaux pris dans une pièce de terrain plus grande.

Les corrélations établies entre les nombres de collemboles et de certains facteurs de l'environnement ont produit des résultats qui étaient incompatibles avec le travail qu'on a fait ci-dessus antérieurement et qui étaient difficiles à interpréter.

On a trouvé dans cette région la répartition agrégée d'une manière caractéristique de collemboles de terre.

Les nombres de collemboles trouvés dans les noyaux pris tout prés de la base d'un arbre ont été plus rares que dans les noyaux pris à une distance plus grande de la base de l'arbre. On a suggéré que ce fait est attribuable peut-être à l'influence de la rhizosphère.

7. Acknowledgments

I am indebted to Dr. C. Overgaard Nielsen for putting the facilities of the Molslaboratoriet, Femmøller, at my disposal.

9. References

Haarløv, N., 1960. Microarthropods from Danish soils. Oikos Suppl. **3**, 176 pp.
Macfadyen, A., 1952. The small arthropods of a Molinia fen at Cothill. J. Anim. Ecol. **22**, 65—77.
Poole, T. B., 1961. An ecological study of the Collembola in a coniferous forest soil. Pedobiologia **1**, 113—137.
— 1963. The effect of some environmental factors on the patterns of distribution of soil Collembola in a coniferous woodland. Pedobiologia **2**, 3, 169—182.

Author's address: Dr. T. B. Poole, Department of Zoology, University College of Wales, Aberystwyth, United Kingdom